

Managed by Fermi Research Alliance, LLC for the U.S. Department of Energy Office of Science

Proton Improvement Plan/Proton Source Ready for 700 KW

W. Pellico
PIP PMG
September 11th 2015

Proton Improvement Plan Goals and Scope (Established in 2011)

- Increase the beam repetition rate from the present ~7.5 Hz to 15 Hz
 - Need at least 9 Hz for NOvA 12-batch slip-stacking
 - Requires RF cavities refurbishment, RF Systems
 - Eliminate major reliability vulnerabilities and maintain reliability at present levels (>85%) at the full repetition rate
- Eliminate major obsolescence issues
 - Increase the proton source throughput, with a goal of reaching >2E17 protons/hour
 - Presently operating at <1E17 protons/hour
- Ensure a useful operating life of the proton source through at least 2025 (now extended to 2030 to accommodate PIP-II schedule)

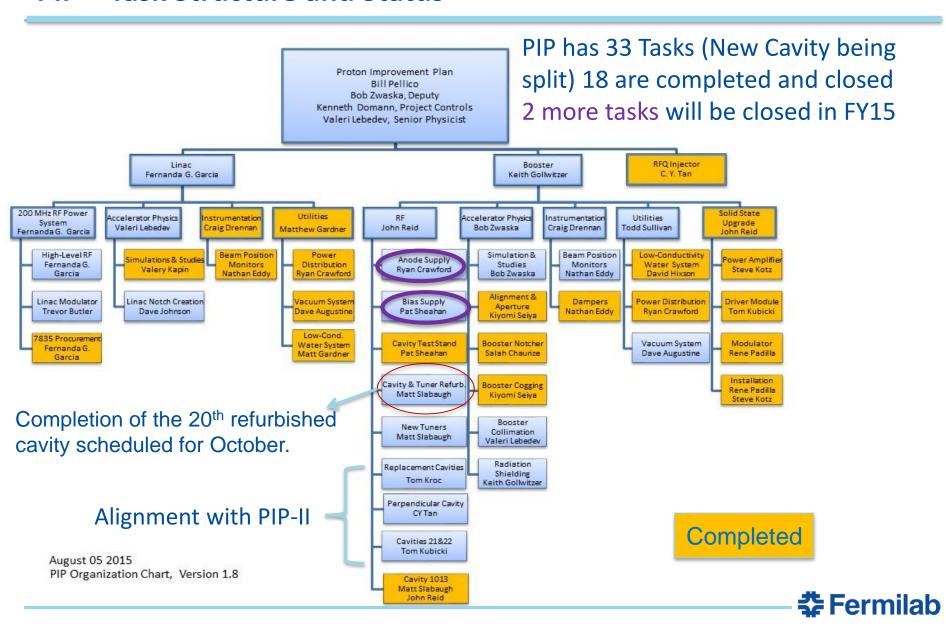


PIP/PS – 700 KW specific flux numbers/goals

- Proton Source plan is to deliver up to 4.3E12/pulse
 Recycler slip stacking for a 1.33 s MI cycle rate
 - For 4x6 slip stacking :
 - Booster Cycle Rate = 7.5 Hz
 - Booster Flux = \sim 1.2E17 protons per hour
 - For 6x6 slip stacking:
 - Booster Cycle Rate = 9 Hz
 - Booster Flux = \sim 1.4E17 protons per hour
- Proton quality and reliability are also part of the deliverables
 - Long term reliability/viability requires completion of PIP



PIP – Task Structure and Status



PIP FY15 Overview

Linac

- 200 MHz Klystron
- 7835 Modulator
- Laser Notcher

in 700 KW operations

Booster

- Cavity Refurbishment
- New Tuners
- Anodes
- Additional station #20
- LCW/Vacuum
- Dampers
- BPMs
- Beam Physics
- 15 Hz
- New Shielding Assessment



Booster/PIP – FY15 Highlights – Items related to 700 KW

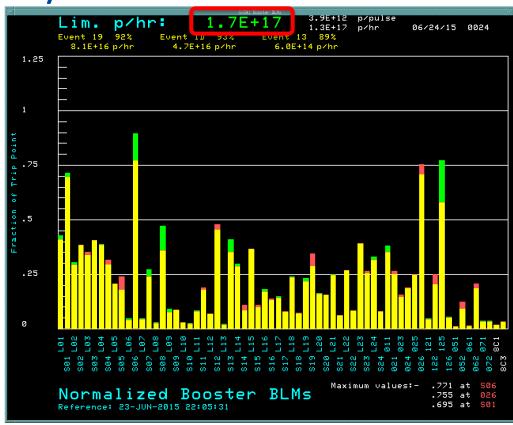
- RF
 - Anode Supplies: proceeding with install (2 Anodes: East and West)
 - East assembled, low power tested with final power testing next week
 - West installed and being populated with hardware 2 more weeks
 - Cavity refurbishment: delivered 17th before shutdown
 - Allowed 15 Hz testing of the entire Booster with beam!!!
 - Bias supplies: pace picked up and we now have 1 remaining
 - Perpendicular Cavity: A 2nd harmonic test cavity is being built
- Beam physics
 - Cogging completed
 - Collimator work started: assigned task manager
 - Lattice work continued: better alignment with measurements
- Instrumentation
 - Longitudinal dampers: completed moving on to commissioning

Booster 15 Hz – A significant achievement for PIP/FNAL

File Options Help 9999999DDDD 9999999DDDD 9999999DDDD 2299999999DDDD 2299999999DDDDD 2299999999DDDD 2299999999DDDD 22

TLG with 13 (fixed target event) beam events & 2 pre-pulses, \$17 (Booster event) then replaced the pre-pulses for full **15** Hz beam operation – record intensity **>1.4E17/hr**!

Loss Limited: \$19 (NoVA event) or \$1D Boone Event) cycles at reduced intensity allowed for 15 Hz beam and some overhead



Booster 15 Hz – with and without beam tests

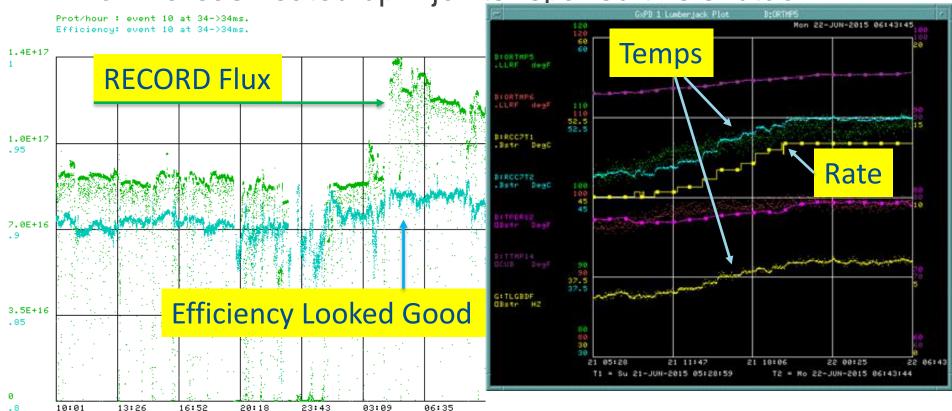
- First attempt in May found weak cavities
- Second attempt worked well for an extended period

06/22/15

06/26/15

06/17/15

Known areas heated up – joints repaired this shutdown



06/09/15

06/13/15

Booster Cavity Refurbishment

- New tuners from TD started to arrive (7 delivered)
- Ferrites are arriving
- Vulnerabilities (longer term)
 - old pie tin leaks
 - ceramic window issues
 - labor
 - Turnover
 - Training
 - Takes lots of time
 - More mistakes occur

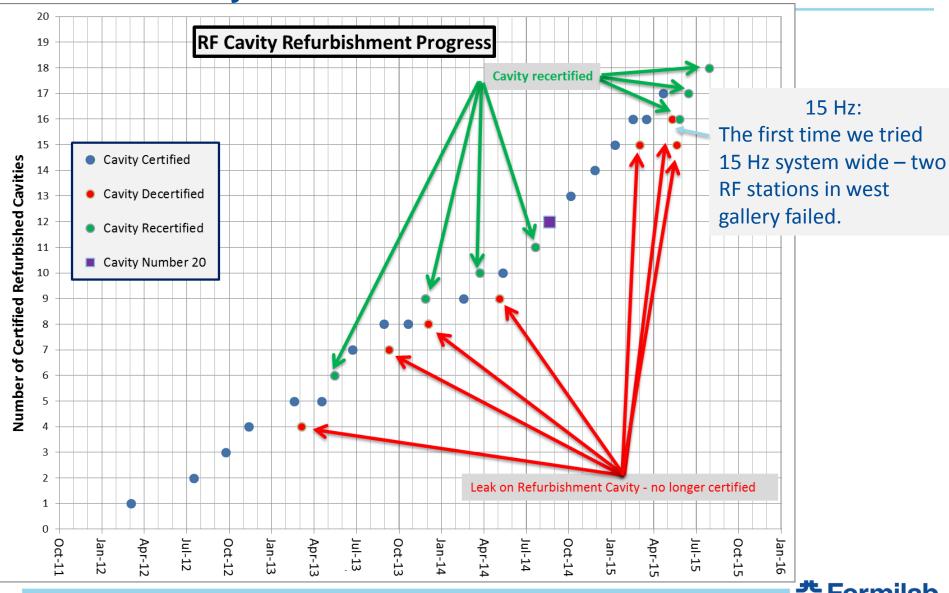


- Cavity #18 done install next week
- Cavity #19 done waiting for high power testing then install
- Cavity #20 refurbishment underway expected in fall (Oct)

We expect require more frequent repair when 15 Hz begins



Booster Cavity Refurbishment



Booster Anode Supplies

New anodes will be capable of powering additional RF stations and long term 15 Hz operations

- Anodes supplies for the Booster RF
 - A lot of effort to finish this system in time
 - Full system test of the first anode (East) is in process...
 - Completion of HV testing scheduled for week of September 14
 - Second supply built mostly in serial about 2 weeks behind East anode
 - Shakedown before beam returns
 - New software/controls
 - New high voltage connections, breakers, fuses, safety systems.....etc
 - One week of HV testing before station (load) testing
 - Have spares and expect some initial shakedown issues/failures



Booster East and West Anode Supplies





East anode assembled and wired: Power testing starting next week

West anode just installed and now being wired (power testing to begin in three weeks)



Booster RF Cavities – No impact to short term 700 KW plan

- Main RF Cavities (FY16)
 - Additional cavities 21 & 22
 - Additional voltage headroom
 - Improve RF manipulations
 - Ensure reliability
 - Develop expertise with cavities
- Replacement Cavities
 - Long term operations
 - Avoid known weak points of existing cavities
 - Higher current operations
 - Compatible with PIP-II+ requirements

- Harmonic Cavity (FY16)
 - Perpendicular biasing
 - Improve injection
 - Design simulations
 - Different garnet geometries
 - Exploring "radial field", an alternate to a solenoidal field
 - Work on testing garnets
 - Better measurements of losses in AL400
 - AL800 testing completed



New Shielding Assessment

- The present limit of 1.8E17 p/hr is above the NoVA 700 KW beam requirement of 1.4E17 p/hr alone but is lower than needed for the lab's full HEP program of 2.4E17 p/hr.
 - Part of the new shielding assessment was to understand present limitations in the beam safety system.
 - Verification of projections and simulations
 - Completion of beam studies
 - Development of a total loss monitor system (TLM) that is more sensitive than our present system.
 - Installed and tested over the past year
 - Approved by lab's ES&H and DOE
 - Final write-up of new assessment underway with completion expected this fall.



Conclusion

- PIP/Proton Source is ready to support 700 KW
 - 15 Hz operation demonstrated
 - Flux required for 700 KW already achieved
 - Labor has been available and has resulted in progress.
 - The completion of the PS/PIP shutdown jobs is tight but expect to be finished before the downstream machines request beam.
 - Ramp up of flux and operations will be challenging but Proton Source does not expect delays in meeting 700 KW numbers.
 - Meeting the long term reliability/viability goals still require the completion of PIP.



backup



PIP FY15 update of FY15 Milestones

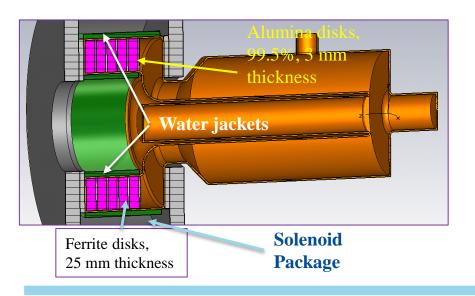
L	WBS	Description	Baseline	Q2 Date	Q3 Date
3	1.02.03.01.02.05	Booster BPM System, Hdw. & Firmware Prototype Design Complete	12/22/14	5/1/15	9/1/15
2	1.02.03.02.01.14	Booster Long. Dampers Complete - boards installed & operational	10/30/14	5/15/15	7/2/15
3	1.01.02.03.03.20	Linac Notch (FA) Certify all three stages ready for installation	12/2/14	5/18/15	8/15/15
3	1.01.02.03.06.23	Linac Notch Beam shaping technology chosen	10/8/14	10/8/14	10/8/14
3	1.02.01.01.03	Specifications for Anode Power Supply Documented	10/15/14	11/26/14	11/26/14
4	1.01.05.02.01.10	Linac LCW System Complete	11/24/14	12/30/14	12/30/14
3	1.01.05.02.02.16	Complete 55 LCW Spare Syst	12/9/14	12/18/14	12/18/14
3	1.02.03.01.01.03	Booster BPM Specification Complete	12/8/14	7/2/15	7/2/15
3	1.01.01.01.02.02	Prototype Klystron Final Assembly Drawings Complete	12/17/14	3/2/15	3/2/15
3	1.02.03.02.01.09	Specifications document for Booster longitudinal dampers complete	12/1/14	3/18/15	3/18/15
3	1.01.02.03.05.33	Linac Notch Final Optical Cavity Certified	2/2/15	10/22/14	10/22/14
3	1.01.02.03.02.26	OPG module ready for installation	2/6/15	5/4/15	7/15/15
4	1.01.05.02.01.09	Complete Installation of New Dual Temp System	3/24/15	12/30/14	12/30/14
4	1.01.01.01.02.01	Final Cost Estimate for Linac Gallery Civil Construction	4/21/15	7/22/15	12/21/15
3	1.01.02.03.04.14	Linac Notch FSLA Operational on Bench - ready to install into OP	4/23/15	6/9/15	8/3/15
3	1.02.03.01.05.02	Booster BPM Production Procure/Assembly Complete	5/15/15	7/21/15	8/21/15
3	1.02.01.02.03.16	Finish program of gutting & assembling within Bias Supply enclosures	4/15/15	6/22/15	8/22/15
2	1.02.02.04.07	Commissioning & Beam Studies - Booster Cogging System Complete	4/14/15	4/15/15	4/15/15
4	1.01.02.03.06.33	Linac Notch Beam Shaping, Diag., Dump ready for installation	9/21/15	2/3/16	2/3/16

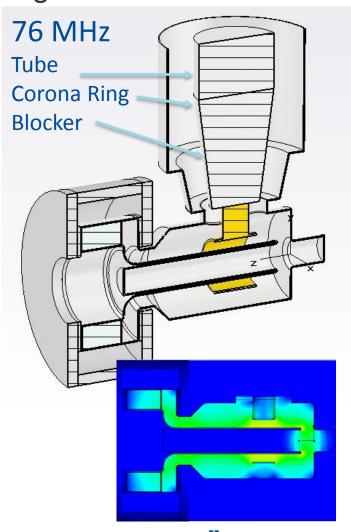


17 PIP 700 KW 9/10/2015

Booster Harmonic Cavity

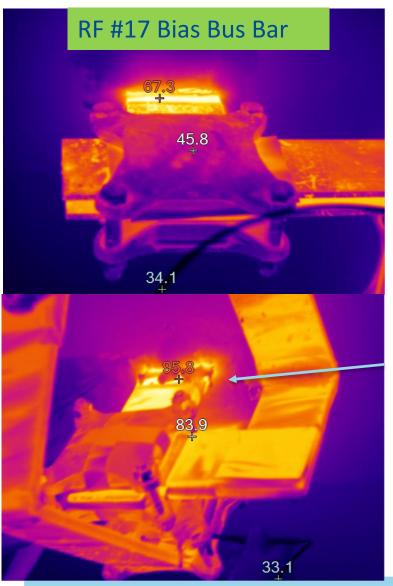
- Beginning mechanical modeling and design
 - Cooling seems to be adequate
 - Amplifier has been ordered
 - Mechanical engineering design started
 - Working on ceramic window design
 - Placement
 - Voltage/vacuum requirements





Access during 15 Hz running to look for issues:

15 Hz temp Examples



~ 96 c Being fixed over shutdown

